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A Design Methodology for Smart LED Lighting Systems Powered By Weakly Regulated Renewable Power Grids

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Abstract—The increasing use of intermittent renewable energy sources to decarbonize electric power generation is expected to introduce dynamic instability to the mains. This situation is of particular concern for mini-grids or isolated grids in which wind and/or solar power sources are the dominant or the sole power sources. In this paper, we utilize the photo-electro-thermal theory to develop a design methodology for LED lighting systems for weakly regulated voltage sources, with the objectives of minimizing the fluctuation of the human luminous perception and adopting reliable LED driver with long lifetime and robustness against extreme weather conditions. The proposed LED system, practically verified in a 10 kVA small power grid driven by an ac voltage source and a wind energy simulator, can be considered as a smart load with its load demand following the power generation. A typical swing of 40 V in the mains will cause only 15% actual light variation in a 132 W LED system when compared with 40% change in 150 W high-pressure-sodium lamp system. The design methodology enables future large-scale LED systems to be designed as a new generation of smart loads that can adapt to the voltage and power fluctuations arising from the intermittent nature of renewable energy sources.

Index Terms—Isolated power grids, light-emitting diodes, lighting systems, mini-grids, renewable power sources, smart loads.

NOMENCLATURE

P_{heat}	Heat generated in each LED.
P_d	LED power.
k_h	A constant representing the portion of P_d that turns into heat.
V_d	Voltage across each LED.
I_d	Current in each LED.

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T_{hs}	Heatsink temperature.
T_a	Ambient temperature.
R_{hs}	Thermal resistance of the heatsink.
R_{jc}	Junction-case thermal resistance of LED device.
k_e	The rate of reduction of the efficacy with junction temperature.
E_o	Luminous efficacy at 25 °C.
T_o	Room temperature of 25 °C.
θ_v	Luminous flux.

I. INTRODUCTION

WITH THE increasing public awareness of global warming, many governments have already decided to substantially increase renewable energy sources as a means to decarbonize electric power generation. For the U.S., U.K., and China, a target of at least 20% of the total electric power generation coming from renewable energy sources has been set for 2020 [1]–[3]. It is envisaged that renewable energy sources will contribute to over 50% by 2050 in some countries. Due to the intermittent nature of renewable energy sources, such as wind and solar energy, potential voltage stability problem arising from the dynamic changing nature of renewable power generation cannot be ignored [4]–[8]. The dynamically changing nature of renewable energy sources could lead to instantaneous energy imbalance particularly in mini or isolated power grids, resulting in poorly regulated voltage mains.

LED lighting has recently been promoted as an emerging technology to replace incandescent and fluorescent lamps [9]–[11]. This project targets the design methodology for LED lighting systems that may be powered by weakly regulated power grids. The essence of the project is to highlight the advantageous features of properly designed LED systems as a new generation of smart loads that may adapt to possible voltage and power fluctuations due to the intermittent nature of renewable energy sources. Examples of applications being considered include public lighting systems such as road lighting. The prime objective is to reduce, as far as possible, the luminous flux variation in the presence of fluctuating mains voltage. The second objective is to adopt reliable lighting technology that has minimum maintenance requirements and long lifetime because public lighting may be subject to extreme weather conditions such as wide temperature changes and lightning.

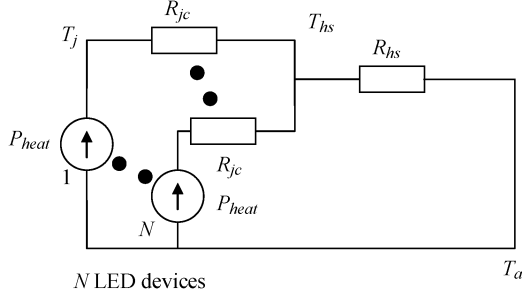


Fig. 1. Simplified steady-state thermal equivalent circuit with N LEDs mounted on the same heatsink [12].

In this paper, the interactions of the photometric, electric, and thermal characteristics of an LED system are first considered. Based on their characteristics as described by the photo-electro-thermal theory [12], a design methodology is proposed so that the variation of the luminous output of the LED lighting system arising from the dynamic fluctuation of the ac mains can be minimized in real time. In particular, the passive LED driver, with only a few circuit components and without using any active power electronic switches and electrolytic capacitors, is used in the design process so as to increase the robustness and reliability of the LED lighting system. An LED lighting system fed by a 10 kVA weakly regulated wind simulator has been set up for practical evaluation. The luminous flux measurements in the presence of dynamic voltage mains fluctuation have recorded as proof of the validity of the proposal.

II. LUMINOUS FLUX OF LED AS A FUNCTION OF HEAT AND POWER

The interactions of the photometric, electric and thermal behaviors of an LED system have been recently addressed in [12]. It has been shown that, for an LED system consisting of N LED devices mounted on the same heatsink, a simple thermal model can be developed as shown in Fig. 1.

The heat generated in each LED is defined as

$$P_{\text{heat}} = k_h P_d = k_h V_d I_d. \quad (1)$$

The procedure for measuring k_h can be found in [9]. The steady-state heatsink temperature T_{hs} can be expressed as

$$T_{hs} = T_a + R_{hs}(N P_{\text{heat}}) = T_a + R_{hs}(N k_h P_d). \quad (2)$$

The junction temperature T_j of each LED is therefore

$$T_j = T_{hs} + R_{jc}(P_{\text{heat}}) = T_{hs} + R_{jc}(k_h P_d). \quad (3)$$

Since the luminous efficacy can be approximated as

$$E = E_o [1 + k_e(T_j - T_o)] \text{ for } E > 0. \quad (4)$$

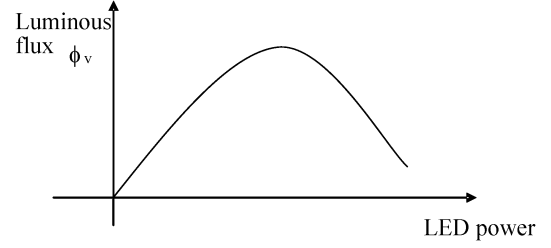


Fig. 2. Relationship of luminous flux and LED power.

The total luminous flux ϕ_v is $\phi_v = N E P_d$

$$\phi_v = N E_o \{ [1 + k_e(T_a - T_o)] P_d + k_e k_h (R_{jc} + N R_{hs}) P_d^2 \}. \quad (5)$$

Equation (5) highlights the relationship of the luminous flux as a function of both power and temperature. For a given heatsink design, such relationship can be graphically shown in Fig. 2. This curve is like a parabolic one. It should be noted that the internal junction temperature of the LED packages exerts strong influence on the luminous output. The theoretical curve (Fig. 2) based on (5) highlights this important point. It can be seen that this curve increases almost linearly when the LED power is small. During this low-power operation, the junction temperature remains low and the luminous efficacy of the LEDs remains high. Thus, the luminous flux increases almost linearly with LED power. As the LED power continues to increase, so does the internal junction temperature. Since the luminous efficacy decreases with increasing internal junction temperature, the luminous flux will reach its peak value and then starts to fall even if the LED power continues to increase, because the detrimental effects of the junction temperature on the luminous efficacy are larger than the increase in LED power of generating more light output. For different thermal designs using different values of R_{hs} , a set of curves can be plotted as a design tool.

III. DESIGN METHODOLOGY

Careful observation of Fig. 2 indicates that top part of the parabolic curve has the smallest sensitivity (i.e., $d\phi_v/dP_d$). As previously mentioned, a weakly regulated power grid has a certain degree of dynamic fluctuation in the mains voltage. If a highly reliable passive LED driver without closed-loop power control, semiconductor switches, and electrolytic capacitor (Fig. 3) [13], [14] is used for powering the LED lighting system, power variation as shown in Fig. 4(a) may occur. However, if the power variation is allowed to occur in the top region of the parabolic curve as shown in Fig. 4(b) or Fig. 4(c), then the variation of the luminous flux remains small. Therefore, a proper thermal design should in principle allow a design of the LED lighting system to be relatively insensitive to the mains voltage fluctuation in a weakly regulated power grid.

Another reason that accounts for the reduction of luminous flux fluctuation is the automatic adjustment of the pupils of human eyes. The relationship between the actual amount of light and human perception is actually nonlinear (following a square

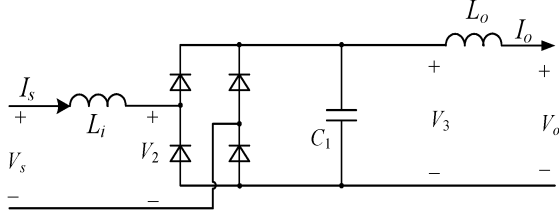


Fig. 3. Passive offline LED driver [14], [18].

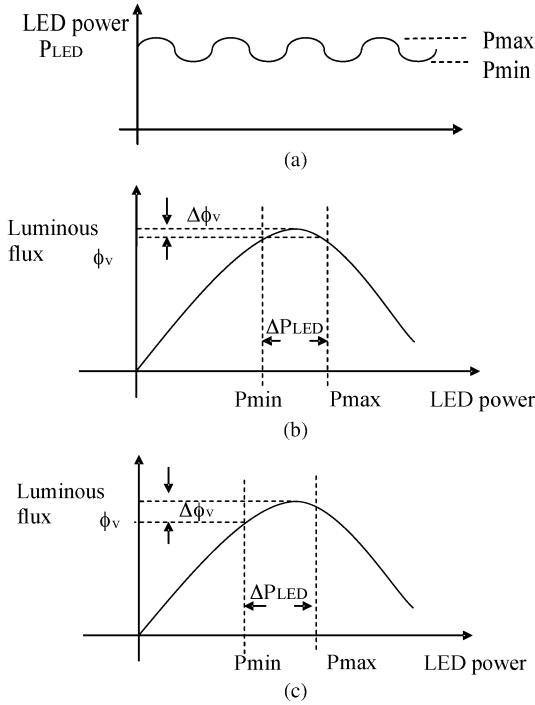
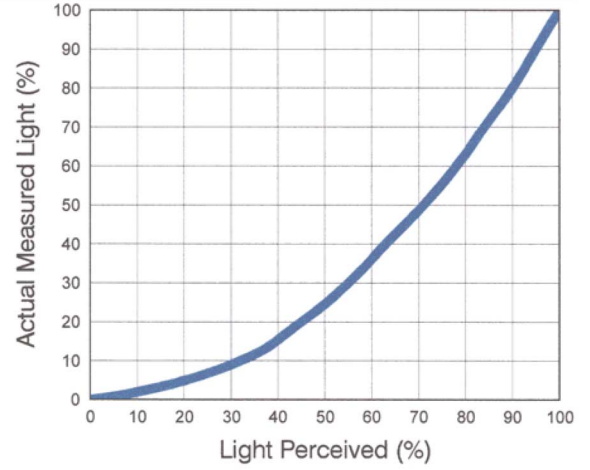


Fig. 4. (a) Typical lamp power variation with small ripple. (b) Example of reducing luminous flux variation using the top region of the flux-power curve. (c) Example of reducing luminous flux variation using the left-hand side of the flux-power curve [13].

law curve) as shown in the website of the Illuminating Engineering Society [15] in Fig. 5. It can be seen that in a well-lit environment, a large reduction of actual light leads to only a small reduction of light in human perception because the pupils will dilate to allow more light to reach the retina. However, in the dark region of this nonlinear curve, a small reduction of actual light will result in a relatively large reduction of light by human eyes because the pupils have fully dilated in a dark environment. Strictly speaking, the curve in Fig. 5 is the scotopic response of human eyes, meaning that it is a curve for a bright environment. For road lighting study, it is more appropriate to use the mesopic response. [Note: Mesopic refers to a regime between a bright environment and a dark environment.] However, there is no standard curve for the mesopic response [15] because it may involve a set of curves. Fig. 5 is the only internationally accepted curve that we can use to provide an indication of human perception of light.

Visual Light Perception

The human eye perceives more than the actual measured light!



The eye perceives light dimmed to 70% as being 84% brightness!

■ Actual vs. Perceived

Illuminating Engineering Society of North America - "Square Law" curve

Fig. 5. Relationship between actual measured light and light perceived [15].

IV. PRACTICAL EVALUATION

A. Design of the LED System With Reduced Luminous Sensitivity to Power Fluctuation

Based on the photo-electro-thermal theory, an LED system with reduced luminous sensitivity to power fluctuation has been designed and developed. The objective of the design is to choose a thermal design so that the luminous flux and LED power follows the parabolic curve as shown in Fig. 4. In this prototype, 36 units of Sharp GW5BC15L02 LED packages are used as an example. It should be noted that systems based on other LED packages can also be characterized accurately by the photo-electro-thermal theory [12]. The LED electro-optical characteristics are listed as follows.

- Output power: 3.7 W (typical); 4.4 W (maximum) per device.
- Forward voltage V_F : 10.2 V (typical) @ I_F 360 mA, T_C 25 °C.
- Luminous flux Φ : 280 lm (minimum) @ I_F 360 mA, T_C 25 °C.
- Package thermal resistance R_{jc} : 6.5 °C/W.

Thirty-six LED devices are arranged on 9 modules to form a 132 W LED lighting system for experimental evaluation. The details of this LED lighting system are listed as follows.

Specifications of LED lighting system:

- Input power: 132 W (typical); 158 W (maximum).
- Total number of LED modules: 9.
- Number of LED devices per module: 4.
- Heat-sink thermal resistance: 5 °C/W.
- The circuit parameters for the passive LED driver (Fig. 3) are: $L_i = 1.44$ H, $L_o = 0.34$ H, and $C_1 = 66$ μ F.

The patented passive LED driver [18] uses two inductors of 1.44 H and 0.34 H. These inductors are of similar sizes of the magnetic chokes used in existing road lighting systems based on

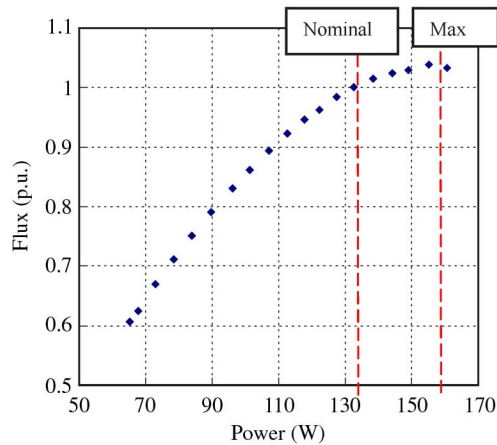


Fig. 6. Measured relationship of the output luminous flux and input power the LED lighting system. (The readings of the luminous flux are normalized to 132 W@220 Vac input.).

high-intensity-discharge (HID) lamps. So there is no size disadvantage. The entire passive LED driver can be housed inside the lamp post. Since the output of the LED driver is a dc current, the cable between the LED driver and the LED fixture does not have to be short. Thus, the passive LED driver can be located near the ground instead of on the top of the lamp post. Based on this thermal design, the relationship of the luminous flux and LED power is measured and plotted in Fig. 6. It can be seen that as the LED power moves along the top region of this curve where the slope is small and the fluctuation of the luminous flux is minimal. In other words, the sensitivity of the luminous flux of this LED system towards the fluctuation of the mains voltage (and thus LED power) has been reduced. The curve of Fig. 6 fits in well with the characteristics as explained in Fig. 4. Another important issue about the choice of the nominal power being set below the maximum rating of the LED package is to improve the lifetime of the LED [17]. Together with the use of the passive LED driver (without electrolytic capacitor, power switches, control electronics, and auxiliary power supply), the proposed LED system offers a highly reliable solution to road lighting systems that are subject to extreme weather conditions such as lightning and wide temperature variations [13]. Consequently, the proposed system can reduce the maintenance requirements.

The relationship of the LED system power with the input ac voltage of the passive LED driver (Fig. 3) is then measured and plotted in Fig. 7. This relationship is found to be fairly linear and will be used to derive the instantaneous luminous flux of the entire LED system. It should be noted that such linear relationship between ac mains voltage and system power is also found in existing magnetic-ballast-driven high-pressure-sodium (HPS) lamps commonly used in road lighting systems as reported in [16].

B. Tests as a Smart Load in a Weakly Regulated Power Grid With Renewable Energy Source

An experimental setup of a small and isolated power grid supplied by a wind-power driven 10 kVA inverter has been set up in the Maurice Hancock Smart Energy Laboratory, Imperial College. A prerecorded wind profile is used by a 10 kV power in-

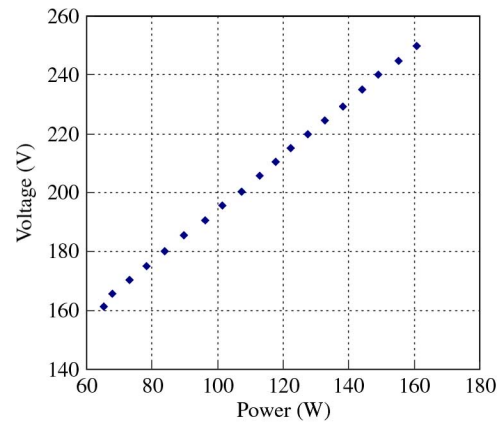


Fig. 7. Measured relationship between input voltage and input power of the 132 W LED lighting system.

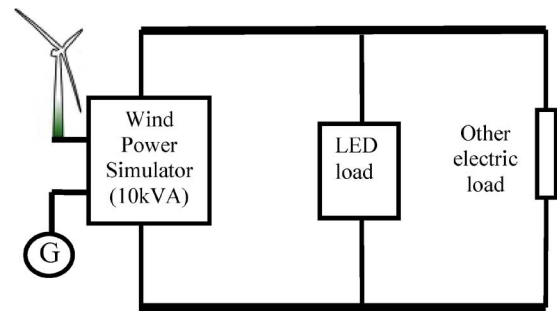


Fig. 8. Schematic of the experimental setup of the power grid and loads.

verter to create a dynamically changing voltage source that is not well regulated. The schematic of the setup is shown in Fig. 8. The weakly regulated power supply is used to feed the proposed lighting system and an electric load. Consequently, the intermittent nature of the wind speed causes the mains voltage to fluctuate. In the setup, the mains voltage varies within the range of 200 V to 240 V, which is larger than the typical $\pm 6\%$ tolerance for an ac mains with a nominal voltage of 220 V.

The measured ac mains voltage and total load power are captured and plotted in Fig. 9. An opto-transistor is used to monitor the instantaneous variation of the light output of the LED system. The actual light variation is recorded and fed into the mapping in Fig. 5 so that the human perceived light can be estimated. The relative variations of the measured ac mains voltage, the measured actual light and the projected human perceived light are plotted in Fig. 10. It can be seen that, a swing of 40 V (from 200 V to 240 V) causes an approximate 35% peak-to-peak power variation, which in turn would lead to a peak-to-peak fluctuation actual light of 15%. The projected peak-to-peak variation of human perceived light is about 7%.

In existing road lighting systems, the dominant technology is still the use of high-intensity-discharge (HID) lamps driven by magnetic ballasts. Such technology has been used for over half of a century. It has been reported in Fig. 9(c) and Fig. 9(d) of [16] that a variation of 40 V in the mains voltage will lead to about 35% change in system power and 46% change in actual light output for 100 W SON-T high pressure sodium (HPS) lamp systems; 32% change in system power and 40% change

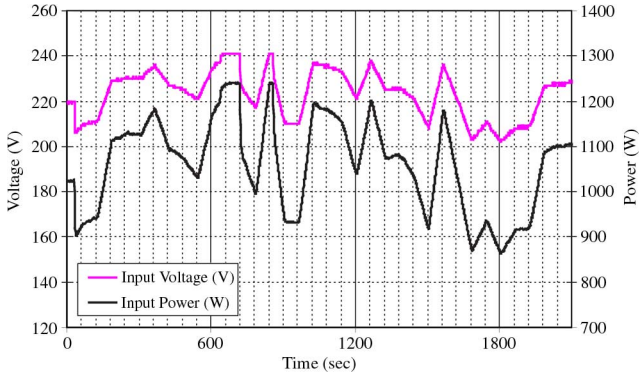


Fig. 9. Measured voltage and input power of the LED lighting system with other resistive load under a weakly regulated renewable power grid set for a nominal value of 220 V.

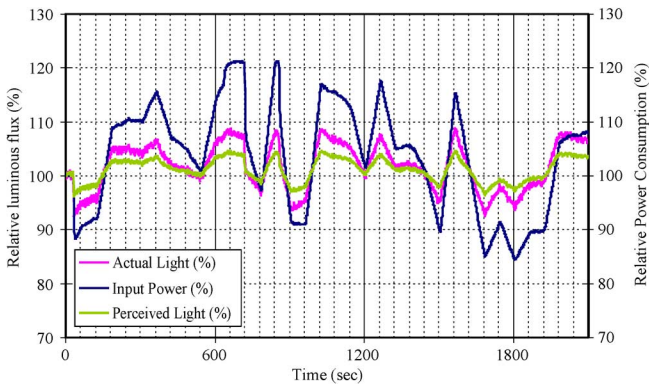


Fig. 10. Measured input power, actual light, and perceived light of the LED lighting system under a weakly regulated renewable power grid.

in actual light output for 150 W SON-T (HPS) lamp systems. The design methodology proposed here suggests that a 40 V swing of ac mains voltage and a corresponding 35% system power variation will result in only 15% actual light variation for a properly designed LED system. Table I shows a comparison of the performance of this passively driven LED system and those of magnetic-ballast driven HPS lamp systems. In both cases, the input power is limited by the input inductor (i.e., L_i of Fig. 3 for the passive LED driver and the magnetic choke for the magnetic ballast). Therefore, the system power variations of the three lighting systems in Table I are similar for the same input voltage variation. However, the actual light variation of the LED system is much smaller than those of the HPS systems of similar power levels. These results indicate that passively driven LED systems may be more suitable than their HPS counterparts for use in weakly regulated renewable power grids because one can take advantage of the parabolic curve of the luminous flux and LED power relationship.

C. Relationship Between Load Demand and Renewable Power Generation

The smart load nature of the LED system designed under the proposed methodology can be observed in Fig. 11 in which both the renewable input power and the LED power are plotted together on two different power scales. It can be seen that the load

TABLE I
COMPARISON OF SYSTEM POWER AND ACTUAL LIGHT VARIATIONS

	Voltage variation	System power variation	Actual light variation
HPS 100W	40V	35%	46%
HPS 150W	40V	32%	40%
LED 132W	40V	35%	15%

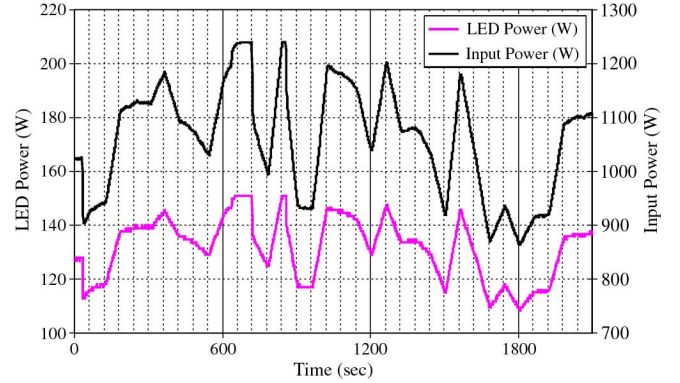


Fig. 11. Variations of the renewable input power and the LED power [Note: load demand follows the renewable power profile.].

demand (i.e., LED power) of the LED system under investigation follows the same profile of the renewable power generation. The automatic load shedding of the LED system under the proposed design methodology has the potential of reducing the energy storage requirement for balancing the power difference between the load demand and power generation.

Presently, there are over 7.5 million street lights in the UK. The majority of them use high-intensity-discharge (HID) lamps of typically 150 W, 250 W, and 400 W. These road lighting systems are operated throughout the nights at full power. Taking an average power of 200 W (including lamp power and ballast loss), the total power consumption of the U.K. road lighting networks would exceed 1500 MW. This could be a sizable smart load that future smart grid can take advantage of. In China, the number of street lamps in major cities exceeds 180 million (or approximately 36 GW).

Collectively, public lighting systems, if properly designed by the proposed methodology, can become a large-scale smart load that:

- 1) can be adaptive to the voltage and power fluctuation of future renewable power systems due to their intermittent nature;
- 2) has its load demand following the power generation profile without causing noticeable light fluctuation;
- 3) has its luminous fluctuation much less than existing lighting systems based on magnetic ballast driven HID lamps for the same voltage change;
- 4) has the potential of reducing the energy storage requirement for smart grids.

V. CONCLUSION

A design methodology of LED systems for used in a weakly regulated renewable power grid has been presented and experimentally verified. The photo-electro-thermal theory for LED

systems is used to develop the thermal design so that the operating point of the LED system can move along the top part of the parabolic curve of the luminous flux and LED power relationship, where the slope and therefore sensitivity of the curve is minimal. The design methodology is practically demonstrated in a 132 W LED system design and implementation. The results obtained from this LED system are compared with typical results of HID lamps of similar power levels. The comparison confirms that the actual light variation of LED system based on the proposed design methodology is much lower than those of HPS lamp systems commonly used in existing road lighting systems.

As the passive LED driver and the LED fixture can offer a highly reliable lighting solution with high robustness against extreme weather conditions and with potential lifetime exceeding 10 years, it is envisaged that such lighting systems, now with a proven feature of reduced light fluctuation, will be attractive to public lighting systems powered by future renewable power grids.

The proposed design methodology enables LED systems to be designed as smart loads that are adaptive to the power and voltage fluctuations of renewable energy systems. Since the power consumption of the LED systems under the design methodology will change with the power profile of the renewable energy source, it is an example of future smart load with load demand following the power generation. Therefore, it has the potential of reducing the energy storage requirements in future smart grids because of the reduction of power difference between the load demand and power generation. Since the road lighting systems are a sizable load in most countries, designing them with a smart load concept can make them adaptive to the intermittent nature of future smart grids with substantial penetration of renewable energy sources. Some advantageous features of such design methodology have been practically confirmed with experiments.

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REFERENCES

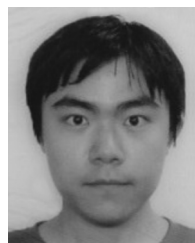
- [1] "Meeting the energy challenge—A white paper on energy," Department of Trade and Industry, U.K. Government, May 2007.
- [2] "China eyes 20% renewable energy by 2020," *China Daily*, June 10, 2009.
- [3] "On investing in the development of low carbon technologies (SET-Plan) a technology roadmap," Brussels, Belgium, Oct. 7, 2009.
- [4] V. Terzija, M. Kayikci, and D. Cai, "Power imbalance estimation in distribution networks with renewable energy resources," in *Proc. 20th Int. Conf. Electr. Distrib.*, Prague, Czech Republic, June 8–11, 2009, CIRED 2009, Paper 0680.
- [5] T. Shimakage, J. Sumita, N. Uchiyama, T. Kato, and Y. Suzuoki, "Supply and demand control of distributed generators in a microgrid," in *Proc. IEEE 30th Int. Telecommun. Energy Conf. (INTELEC 2008)*, pp. 1–5, .

- [6] *Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy*, B. Moselle, J. Padilla, and R. Schmalensee, Eds. Washington, DC: RFF Press, Aug. 2010.
- [7] Q. Chen, C. Kang, Q. Xia, and J. Zhong, "Power generation expansion planning model towards low-carbon economy and its application in China," *IEEE Trans. Power Syst.*, vol. 25, no. 2, pp. 1117–1125, 2010.
- [8] P. P. Varaiya, F. F. Wu, and J. W. Bialek, "Smart operation of smart grid: Risk-limiting dispatch," *Proc. IEEE*, vol. 99, no. 1, pp. 40–57, 2011.
- [9] D. Gacio, J. M. Alonso, A. J. Calleja, J. García, and M. Rico-Secades, "A universal-input single-stage high-power-factor power supply for HB-LEDs based on integrated buck-flyback converter," *IEEE Trans. Ind. Electron.*, vol. 58, no. 2, pp. 589–599, 2011.
- [10] H.-J. Chiu, Y.-K. Lo, J.-T. Chen, S.-J. Cheng, C.-Y. Lin, and S.-C. Mou, "A high-efficiency dimmable LED driver for low-power lighting applications," *IEEE Trans. Ind. Electron.*, vol. 57, no. 2, pp. 735–743, 2010.
- [11] L. Gu, X. Ruan, M. Xu, and K. Yao, "Means of eliminating electrolytic capacitor in AC/DC power supplies for LED lighting," *IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1399–1408, 2009.
- [12] S. Y. R. Hui and Y. X. Qin, "A general photo-electro-thermal theory for light emitting diode (LED) systems," *IEEE Trans. Power Electron.*, vol. 24, no. 8, pp. 1967–1976, Aug. 2009.
- [13] S. Y. R. Hui, S. Li, W. Chen, X. H. Tao, and W. M. Ng, "A novel passive LED drivers with long lifetime," *IEEE Trans. Power Electron.*, vol. 25, no. 10, pp. 2665–2672, 2010.
- [14] W. Chen, S. N. Li, and S. Y. R. Hui, "A comparative study on the circuit topologies for offline passive light-emitting diode (LED) drivers with long lifetime & high efficiency," in *Proc. IEEE Energy Convers. Congr. Expo. (ECCE)*, 2010, pp. 724–730.
- [15] Illuminating Engineering Society Web site [Online]. Available: <http://www.iesna.org>
- [16] W. Yan, S. Y. R. Hui, and H. S.-H. Chung, "Energy saving of large-scale high-intensity-discharge lamp lighting networks using a central reactive power control system," *IEEE Trans. Ind. Electron.*, vol. 56, no. 8, pp. 3069–3078, 2009.
- [17] N. Narendran, Y. Gu, J. P. Freyssiener, H. Yu, and L. Deng, "Solid-state lighting: Failure analysis of white LEDs," *J. Crystal Growth*, vol. 268, pp. 449–456, 2004.
- [18] S. Y. R. Hui and W. Chen, "Apparatus and methods of operation of passive LED lighting equipment," U.S. patent application 12/429792 Apr. 24, 2009.



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